AMENDMENTS TO THE CLAIMS:

This listing of claims will replace all prior versions, and listings of claims in the application:

LISTING OF CLAIMS:

1. (cancelled)

2. (currently amended) A method according to claim 8 ~~1~~, for simulating an oscillating phenomenon, wherein the digital model comprises, on the one hand at least one linear part (3), representing the input impedance or admittance of the resonator, and, on the other hand, one non-linear part (2) modelization the role of the excitation source (22) of the phenomenon to be simulated.

3. (currently amended) A simulation method according to claim 8 ~~1~~, for real time digital synthesis of an oscillating phenomenon, wherein, from a system of equations between at least two variables representative of the behaviour of a wave in the resonator, an expression of the input impedance or admittance of the resonator is established in the form of a linear filter including delays, without any decomposition into two-way waves, in order to realise at least one linear part (3) of the model.

4. (original) A method according to claim 3, wherein the linear part (3) of the model is coupled with one non-linear part (2) involving the evolution of the non-linearity as expressed between the two variables of the input impedance or admittance relation of the resonator.

5. (original) A method according to claim 4, wherein the

linear part (3) of the digital simulation model of the impedance or admittance equation in based on to two elementary waveguides fulfilling a transfer function between the two variables of the impedance or admittance relation.

6. (original) A method according to claim 5, wherein the linear part (3) with two waveguides of the model is coupled with a loop connecting the output to the input of said linear part (3) and comprising a function (21) involving the non-linearity as expressed physically.

7. (original) A method according to claim 6, wherein the model is driven by at least two parameters representative of the non-linear physical interaction between the source and the resonator, by means of a loop connecting the output to the input of the linear part (3) and comprising a non-linear function (21) playing the part of an excitation source for the resonator.

8. (currently amended) A digital simulation method of a non-linear interaction between an excitation source and a wave in a resonator, by means of digital signal calculation tools based on equations the solution of which corresponds to the physical event of a phenomenon to be simulated which can translated, at each time and at each point of the resonator, by a linear relation between two variables representative of the effect and of the cause of said phenomenon to be simulated comprising:

transcribing the impedance or admittance equation directly into a digital model form enabling to realise a non-linear interaction between the two variables of the impedance or admittance relation,

~~A method according to claim 1,~~ wherein said method is adapted for real-time sound synthesis of a musical instrument comprising, at least, one excitation source with non-linear characteristics

and a linear resonator, the sound produced by the instrument resulting from a coupling, between the excitation source and the resonator, expressed at least by a linear impedance or admittance relation and a non-linear relation between two physical variables representative of the effect and of the cause of the sound produced, a method where the sound produced by the instrument is simulated, in real time, by modelization the physical phenomena governing the operation of the instrument, wherein, to realise said physical modelization, the impedance or admittance linear relation is expressed directly and digitally between two physical variables representative of the cause and of the effect of the phenomenon to be simulated and said impedance or admittance relation in digital form is associated with the non-linear relation between the same variables.

9. (original) A method according to claim 8 for synthesis of the sound of an instrument with complex resonator, wherein the resonator is decomposed into a series of successive elements and wherein the impedance or admittance relations corresponding respectively to each element of the resonator are calculated and combined in order to obtain a global impedance corresponding to the geometry of the resonator.

10. (previously presented) A method according to claim 8, wherein, for real-time synthesis of the sound produced by a wind instrument, the two variables of the impedance relation are the acoustic pressure (p_e) and flow (u_e) at the input of the resonator.

11. (original) A method according to claim 10, wherein, for an open-ended cylindrical resonator, the linear part (3) of the digital transcription model of the impedance equation is the sum of two elementary waveguides having as excitation source the flow (u_e) at the input of the resonator, and fulfils the transfer

function :

$$Z_e(\omega) = \frac{Pe(\omega)}{Ue(\omega)} = \frac{1}{1+\exp(-2ik(\omega)L)} - \frac{\exp(-2ik(\omega)L)}{1+\exp(-2ik(\omega)L)}$$

(12)

wherein:

ω is the angular frequency of the wave ;

$Ze(\omega)$ is the input impedance of the resonator,

$Pe(\omega)$ and $Ue(\omega)$ are the Fourier transforms of the dimensionless values of the pressure and of the flow at the input of the resonator ;

$k(\omega)$ is a function of the angular frequency which depends on the phenomenon to be simulated ;

L is the length of the resonator.

12. (original) A method according to claim 11, wherein each of the two waveguides involves a filter having as a transfer function:

$$-F(\omega)^2 = -\exp(-2ik(\omega)L)$$

and representing a two-way travel of a wave, with a sign change at the open end of the resonator, each waveguide corresponding to a term of the impedance equation.

13. (original) A method according to claim 12, wherein the model is driven by the length (L) of the resonator and at least two parameters (ζ, γ) representative of the non-linear physical interaction between the pressure (p_e) and the flow (u_e) at the input of the resonator, by means of a loop connecting the output to the input of the linear part (3) and comprising a non-linear function (21) as an excitation source for the resonator.

14. (original) A method according to claim 11, wherein the non-linear function has the pressure and the displacement of the vibration formation member as input parameters, and is controlled by at least two parameters simulating a player playing.

15. (original) A method according to claim 14, wherein the playing parameters for controlling the non-linear function are:

a parameter ς characteristic of the mouthpiece and of the action of the player on the vibration formation member,

a parameter γ representative of the pressure applied to the vibration formation member.

16. (previously presented) A method according to claim 10, wherein, for real-time synthesis of the sound to be simulated, a formulation is realised in the time domain of the angular frequency response of the impedance of the resonator, by approximation of the losses represented by the filter by means of an approximated digital filter.

17. (original) A method according to claim 16, wherein, to express the angular frequency response of the impedance of the resonator, a one pole digital filter is used of the form:

$$\tilde{F}(\varpi) = \frac{b_o \exp(-2i\varpi D)}{1 - a_1 \exp(-i\varpi)} \qquad (13)$$

wherein :

$\varpi = \frac{\omega}{f_e}$, fe being the sampling frequency,

$D = f_e \frac{L}{c}$ is the pure delay corresponding to an away or return travel of the wave in the resonator,

- the coefficients bo and a1 are expressed in relation to the physical parameters so that $\left|F(\omega)^2\right|^2 = \left|\tilde{F}(\varpi)\right|^2$ for a value ω1 of the angular frequency corresponding to the fundamental playing frequency and another value ω2 corresponding to a harmonic,

and the following differential equation is derived:

$$p_e(n) = u_e(n) - a_1 u_e(n-1) - b_0 u_e(n-2D) + a_1 p_e(n-1) - b_0 p_e(n-2D) \quad (16)$$

18. (original) A method according to claim 17, wherein the coefficients bo and a1 are obtained by solving the equation system:

$$\left|F(\omega_1)^2\right|^2 (1 + a_1^2 - 2a_1 \cos(\varpi_1)) = b_0^2$$

$$\left|F(\omega_2)^2\right|^2 (1 + a_1^2 - 2a_1 \cos(\varpi_2)) = b_0^2$$

with $\left|F(\omega)^2\right|^2 = \exp(-2\alpha c \sqrt{\frac{\omega}{2}} L)$, said coefficients being given by the formulae:

$$a_1 = \frac{A1 - A2 - \sqrt{(A_1 - A_2)^2 - (F_1 - F_2)^2}}{F_1 - F_2}$$

$$b_0 = \frac{\sqrt{2F_1F_2(c_1 - c_2)(A_1 - A_2 - \sqrt{(A_1 - A_2)^2 - (F_1 - F_2)^2})}}{F_1 - F_2}$$

wherein

$$c_1 = \cos(\varpi_1), c_2 = \cos(\varpi_2), F_1 = \left|F(\omega_1)^2\right|^2, F_2 = \left|F(\omega_2)^2\right|^2,$$

$$A_1 = F_1 c_1, A_2 = F_2 c_2$$

19. (original) A method according to claim 18, for simulating a cylindrical resonator instrument, from a physical modelization governed by the system of equations :

$$\frac{1}{\omega_r^2}\frac{d^2x(t)}{dt^2} + \frac{q_r}{\omega_r}\frac{dx(t)}{dt} + x(t) = \pm p_e(t)$$

(with the sign + for a reed and the sign - for the lips)

$$P_e(\omega) = i\tan\left(\frac{\omega L}{c} - \frac{i^{3/2}}{2}\alpha c \omega^{1/2} L\right) U_e(\omega)$$

$$u_e(t) = \frac{1}{2}(1 - \mathrm{sign}(\gamma - x(t) - 1))\mathrm{sign}(\gamma - p_e(t))\zeta(1 - \gamma + x(t))\sqrt{|\gamma - p_e(t)|}$$ wherein ωr is the resonance frequency and qr is the quality factor of the reed or of the lips, wherein that said system of equations is solved in the time domain from an equivalent sampled formulation of the angular frequency response of the displacement of the reed or of the lips and of the impedance relation which is translated by the system of equations :

$$x(n) = b_{1a} p_e(n-1) + a_{1a} x(n-1) + a_{2a} x(n-2) \quad (18)$$

$$p_e(n) = u_e(n) - a_1 u_0 \ (n-1) - b_0 u_e(n-2D) + a_1 p_e(n-1) b_0 p_e(n-2D)$$

(19)

$$u_e(n) = \frac{1}{2}(1 - \mathrm{sign}(\gamma - x(n) - 1))\mathrm{sign}(\gamma - p_e(n))\zeta n) - \gamma + x(n))\sqrt{|\gamma - p_e(n)|} \quad (20)$$

said equations being used sequentially by grouping the terms not depending on the time sample n, in order to calculate in succession :

$$x(n)=b_{1a}p_e(n-1)+a_{1a}x(n-1)+a_{2a}x(n-2)$$

(21)

$$V=-a_1u_e(n-1)-b_0u_e(n-2D)+a_1p_e(n-1)-b_0p_e(n-2D)$$

(22)

$$W = \frac{1}{2}(1 - \mathrm{sign}(\gamma - x(n) - 1))\zeta)) - \gamma + x(n))$$

(23)

$$u_e(n) = \frac{1}{2}\mathrm{sign}(\gamma - V)(-bc_0W^2 + W\sqrt{(bc_0W)^2 + 4|\gamma - V|} \quad (24)$$

$$p_e(n)=b_0c_0u_e(n)+V$$

(25)

20. (original) A method according to claim 19, for more realistic simulation of the produced sound, wherein, by neglecting the radiation, the external pressure is expressed as the time derivation of the outgoing flow, in the form:

$$p_{ext}(t) = \frac{d}{dt}\left(p_e(t) + u_e(t)\right)$$

(26)

and is calculated, at each sampled time (n), by differential between the sums of the internal pressure pe and of the flow ue, respectively at the time (n) and at time (n-1).

21. (original) A method according to claim 19 for simulating a multimode reed instrument, wherein the calculation of the acoustic pressure and of the flow at the mouthpiece is performed by sequential resolution of a system of equations wherein the displacement of the reed at each time(n) is in the form:

$x(n)=b_{a1}p_e(n-1)+b_{a2}p_e(n-2)+b_{aD1}p_e(n-D_a-1)+a_{a1}x(n-1)+a_{a2}x(n-2)+a_{aD}x(n-D_a)+a_{aD1}x(n-D_a-1)$

the coefficients aa1, aa2, aaD2, aaD1 being defined by:

$$a_{a1}=\frac{f_e(1+a_a)-\beta}{f_e},\quad a_{a2}=\frac{a_a(\beta-f_e)}{f_e},\quad a_{aD}=-b_a,\quad a_{aD1}=\frac{b_a(f_e-\beta)}{f_e}$$

and the coefficients ba1, ba2, baD1 by :

$$b_{a1}=\frac{C}{fe},\quad b_{a2}=\frac{-Ca_a}{fe},\quad b_{aD1}=\frac{-Cb_a}{fe}.$$

$$\beta=\frac{1}{2}\omega_r q_r \quad \text{et} \quad C=\frac{A_3-\sqrt{A_3}}{\left(\sqrt{A_3}-1\right)q_r A_1} \tag{28}$$

by setting : $A_1=\frac{2}{\omega_r\sqrt{q_r^2+4}}$, $A_2=\frac{1}{2}\omega_r q_r$ and $A_3=A_2A_1q_r$,

the following equations being the same as for a single mode reed.

22. (previously presented) A method according to one claim 19, wherein that a model is prepared for a cylindrical resonator with terminal impedance from the basic model corresponding to a cylindrical resonator and being the sum of two waveguides involving each a filter having as a transfer function $-F(\omega)^2=-\exp(-2ik(\omega)L)$,

while replacing the expression exp(-2ik(ω)L) by the expression

$R(\omega)\exp(-2ik(\omega)L)$, wherein $R(\omega) = \dfrac{Z_c - Z_s(\omega)}{Z_c + Z_s(\omega)}$

Zc being the characteristic impedance

$\dfrac{\rho c}{\pi R^2}$ etZ_s the output impedance $\dfrac{P_s(\omega)}{U_s(\omega)}$

23. (previously presented) A method according to claim 19, wherein, from the impedance model for cylindrical resonator instrument and the associated differential equations, other more complex impedance models are built for simulating oscillating phenomena produced by a resonator of any shape by combining impedance elements in parallel or in series and by using digital approximations for an explicit use of the physical variables involved in the production of said oscillating phenomena and a more flexible control of the result of the simulation.

24. (previously presented) A method according to claim 23, wherein that, from the basic model of a cylindrical resonator wherein the angular frequency response of the displacement of the reed or of the lips is translated by a system of differential equations providing, at each time(n), the displacement x(n) the pressure pe(n) and the flow ue(n) at the input of the resonator, a model for a conical resonator is built wherein the equation of the pressure is in the form:

$$p_e(n) = bc_0u_e(n) + bc_1u_e(n-1) + bc_2u_e(n-2) + bc_Du_e(n-2D) + bc_{D1}u_e(n-2D-1)$$
$$+ ac_1p_e(n-1) + ac_2p_e(n-2) + ac_Dp_e(n-2D) + ac_{D1}p_e(n-2D-1) \quad (33)$$

wherein the coefficients bc0, bc1, bc2, bcD and bcD1 are defined by :

$bc_0 = \frac{1}{G_p}$, $bc_1 = -\frac{a_1+1}{G_p}$, $bc_2 = \frac{a_1}{G_p}$, $bc_D = -\frac{b_{01}}{G_p}$, $bc_{D1} = \frac{b_0}{G_p}$

and the coefficients ac_1, ac_2, ac_D and ac_{D1} are defined by :

$$ac_1 = -\frac{a_1 G_p + G_m}{G_p}, \quad ac_2 = \frac{a_1 G_m}{G_p}, \quad ac_D = -\frac{b_0 G_m}{G_p}, \quad ac_{D1} = b_0$$

by noting : $G_p = 1 + \frac{1}{2f_e \frac{x_e}{c}}$ and $G_m = 1 - \frac{1}{2f_e \frac{x_e}{c}}$,

25. (previously presented) A method according to claim 24 wherein that, from the basic model for a cylindrical resonator, a model for a short resonator having a length l is built, by an approximation of the impedance according to the expression:

$$Z_1(\omega) = i \tan(k(\omega)l) \cong G(\omega) + i\omega H(\omega) \tag{34}$$

wherein $G(\omega) = \frac{1 - \exp\left(-\alpha c \sqrt{\frac{\omega}{2}}\, l\right)}{1 + \exp\left(-\alpha c \sqrt{\frac{\omega}{2}}\, l\right)}$ and $H(\omega) = \frac{1}{c}(1 - G(\omega))$.

26. (previously presented) A method according to claim 25 for simulating a wind instrument, wherein the mouthpiece or the bill is modelled by a Helmholtz resonator comprising a hemispheric cavity coupled with a short cylindrical pipe and a main resonator with a conical pipe, the input impedance of the resonator assembly which may be expressed as:

$$Z_e(\omega)=\cfrac{\cfrac{1}{Z_n}}{i\omega\cfrac{V}{\rho c^2}+\cfrac{1}{iZ_1(k_1(\omega)L_1)+Z_2\cfrac{i\omega\cfrac{x_e}{c}}{1+\cfrac{i\omega\cfrac{x_e}{c}}{i\tan(k_2(\omega)L_2)}}}}$$

wherein $V=\frac{4}{6}\pi R_b^3$ is the volume of the hemispheric cavity, L1 is the length of the short pipe, L2 is the length of the conical pipe, Z1 and Z2 are the characteristic impedances of both pipes which depend on their radii, $k1(\omega)$ and $k2(\omega)$ take into account the losses and the radius R1 and R2 of each pipe, and that, from the basic model for cylindrical resonator, from its extensions to the conical pipe and to the short pipe, a resonator model is prepared by expressing the pressure at the mouthpiece or in the bill by the differential equation :

$$p_e(n)=\sum_{k=0}^{k=4}bc_k u_e(n-k)+\sum_{k=0}^{k=3}bc_{Dk}u_e(n-k-2D) + \sum_{k=1}^{k=4}ac_k p_e(n-k)+\sum_{k=0}^{k=3}ac_{Dk}p_e(n-k-2D) \qquad (36)$$

27. (currently amended) A method according to claim <u>8</u> ~~1~~, for the simulation of an oscillating phenomenon wherein both physical variables of the linear relation are the strength applied to one point of a mechanical system such as a string generating vibrations and the speed at this point, wherein that the admittance is expressed, at this point, in the form of a combination of the admittances of each part of the string, on both

sides of said point, each mechanical admittance being obtained from the basic model describing the acoustic impedance of a cylindrical pipe resonator, by expressing the speed at the point considered of the string in relation to the strength applied to this point, where the filter $F(\omega)$ of the basic model may be expressed from a bending wave propagation model in a having a stiffeness.

28. (previously presented) A digital device to implement the method according to claim 8, for the simulation of a musical instrument generating a sound resulting from a coupling between a linear resonator and an excitation source with a non-linear characteristic, which can be expressed at least by a linear impedance or admittance relation and a non-linear relation between two variables representative of the effect and of the cause of the produced sound, said simulation device comprising a control element I including at least one gestural sensor 1 transforming the actions of a player into control parameters, a modelization element II including one non-linear part (2) associated with a linear part (3) and an element creating the synthesised sound III, wherein that the linear part (3) includes a computing block (31) driven by the length (L) of the resonator, having as an input parameter a signal representative of one of the variables, cause or effect, computed by the non-linear part (2), and the transfer function of which is the input impedance or admittance of the resonator, in that the non-linear part (2) implements a non-linear function (21) driven by at least two control parameters and having as input parameters a signal representative of the other variable, cause or effect, computed by the linear part (3) and a signal modelization the role of the excitation source, the linear part (3) being thus coupled with the non-linear part (2) in a closed loop, and in that the element creating the sound III computes a sound signal from signals representative of the cause and of the

effect of the sound to be simulated, emitted respectively by the linear part (3) and the non-linear part (2).

29. (previously presented) A method according to claim 19, wherein that, from the basic model of a cylindrical resonator wherein the angular frequency response of the displacement of the reed or of the lips is translated by a system of differential equations providing, at each time(n), the displacement x(n) the pressure pe(n) and the flow ue(n) at the input of the resonator, a model for a conical resonator is built wherein the equation of the pressure is in the form:

$$p_e(n) = bc_o u_e(n) + bc_1 u_e(n-1) + bc_2 u_e(n-2) + bc_D u_e(n-2D) + bc_{D1} u_e(n-2D-1)$$

$$+ ac_1 p_e(n-1) + ac_2 p_e(n-2) + ac_D p_e(n-2D) + ac_{D1} p_e(n-2D-1) \qquad (33)$$

wherein the coefficients bc0, bc1, bc2, bcD and bcD1 are defined by :

$$bc_0 = \frac{1}{G_p}, \quad bc_1 = -\frac{a_1+1}{G_p}, \quad bc_2 = \frac{a_1}{G_p}, \quad bc_D = -\frac{b_{01}}{G_p}, \quad bc_{D1} = \frac{b_0}{G_p}$$

and the coefficients ac_1, ac_2, ac_D and ac_{D1} are defined by :

$$ac_1 = -\frac{a_1 G_p + G_m}{G_p}, \quad ac_2 = \frac{a_1 G_m}{G_p}, \quad ac_D = -\frac{b_0 G_m}{G_p}, \quad ac_{D1} = b_0$$

by noting : $G_p = 1 + \dfrac{1}{2f_e \dfrac{x_e}{c}}$ and $G_m = 1 - \dfrac{1}{2f_e \dfrac{x_e}{c}}$,

30. (previously presented) A method according to claim 19 wherein that, from the basic model for a cylindrical resonator, a

model for a short resonator having a length l is built, by an approximation of the impedance according to the expression:

$$Z_l(\omega) = i \tan(k(\omega)l) \cong G(\omega) + i\omega H(\omega) \tag{34}$$

wherein $G(\omega) = \dfrac{1 - \exp\left(-\alpha c\sqrt{\dfrac{\omega}{2}}\, l\right)}{1 + \exp\left(-\alpha c\sqrt{\dfrac{\omega}{2}}\, l\right)}$ and $H(\omega) = \dfrac{l}{c}(1 - G(\omega))$.